

***2001 National
Workshop on State
Building Energy Codes
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Burlington, Vermont***

**A Systems Engineering Approach
to the Design of
Energy and Resource Efficient
Homes**

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Why is Moisture Important?

- Moisture damage contributes to over 90% of all building and building material failures (ASHRAE)
- Except for structural errors, moisture is the leading cause of building problems costing more than 9 billion dollar annually in the US. (ASTM)
- Moisture-related problems lead the list of top callbacks for most builders.
- Several consumer surveys list moisture problems as a primary concern

Why is Indoor Air Quality Important?

- In 1994, EPA ranks health risks of 26 leading environmental hazards. The top concern was indoor pollution.
- Indoor air quality has been demonstrated to be many times worse than outdoor air quality
- We spend 90% of our day indoors and 65% of that is in our homes
- Asthma rates have increased dramatically in the last 12 years. Adults up 61%. Children up 72%.

Trends in Building Technology

- Improved safety
- Healthier indoor environments
- Energy efficiency
- Increased building durability
- Affordability
- Resale value
- Improved comfort
- Intentional ventilation

The Rules of Building

- Moisture moves from more to less
- Moisture move from warm to cold
- Heat flows from warm to cold
- CFM (air) out equals CFM (air) in
- Drain the rain
- Things always get wet - let them dry
- Heat, air & moisture are one
- It happens at the surface
- Keep clients out of harms way

Characteristics of Many Older Buildings

- Leaky and drafty
- Poor insulation
- High energy use
- Uncomfortable
- Natural ventilation
- Materials get wet & can sometimes dry

Characteristics of Many Newer Buildings

- Tighter construction
- Higher insulation levels
- Lower energy use
- More comfortable
- Poor ventilation
- Indoor air quality problems
- Moisture problems

Characteristics of Improved Buildings

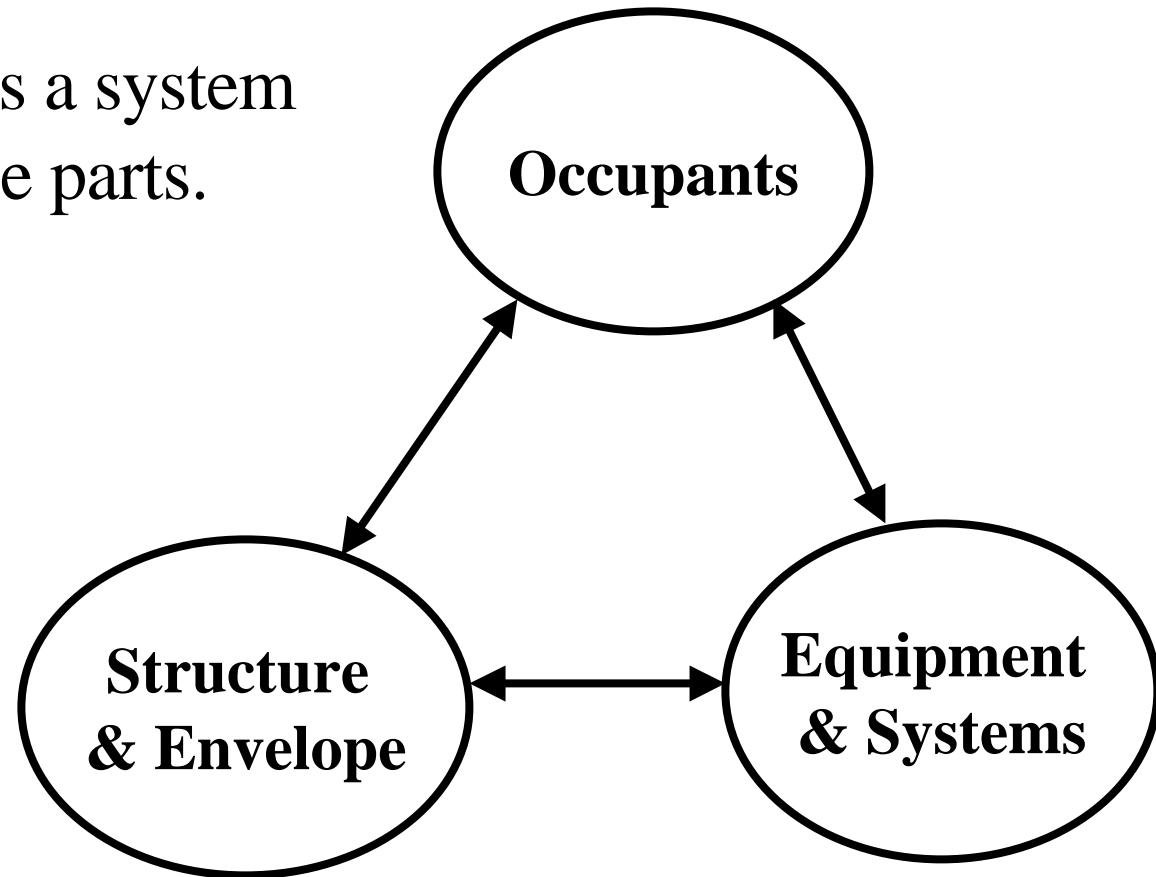
- Very tight construction
- Carefully insulated
- Low energy use
- High comfort level
- Mechanical ventilation
- Good indoor air quality
- Reduced moisture problems
- Durable and low maintenance

Who Benefits from Improved Buildings?

- Building Owners & Occupants
 - Improved comfort & energy savings
 - Healthier indoor air
- Building Industry
 - Reduced callbacks
 - Reduced potential liability
- Society
 - Improved building stock
 - Better economy & environment

How do Buildings Work?

- A building is a system of interactive parts.

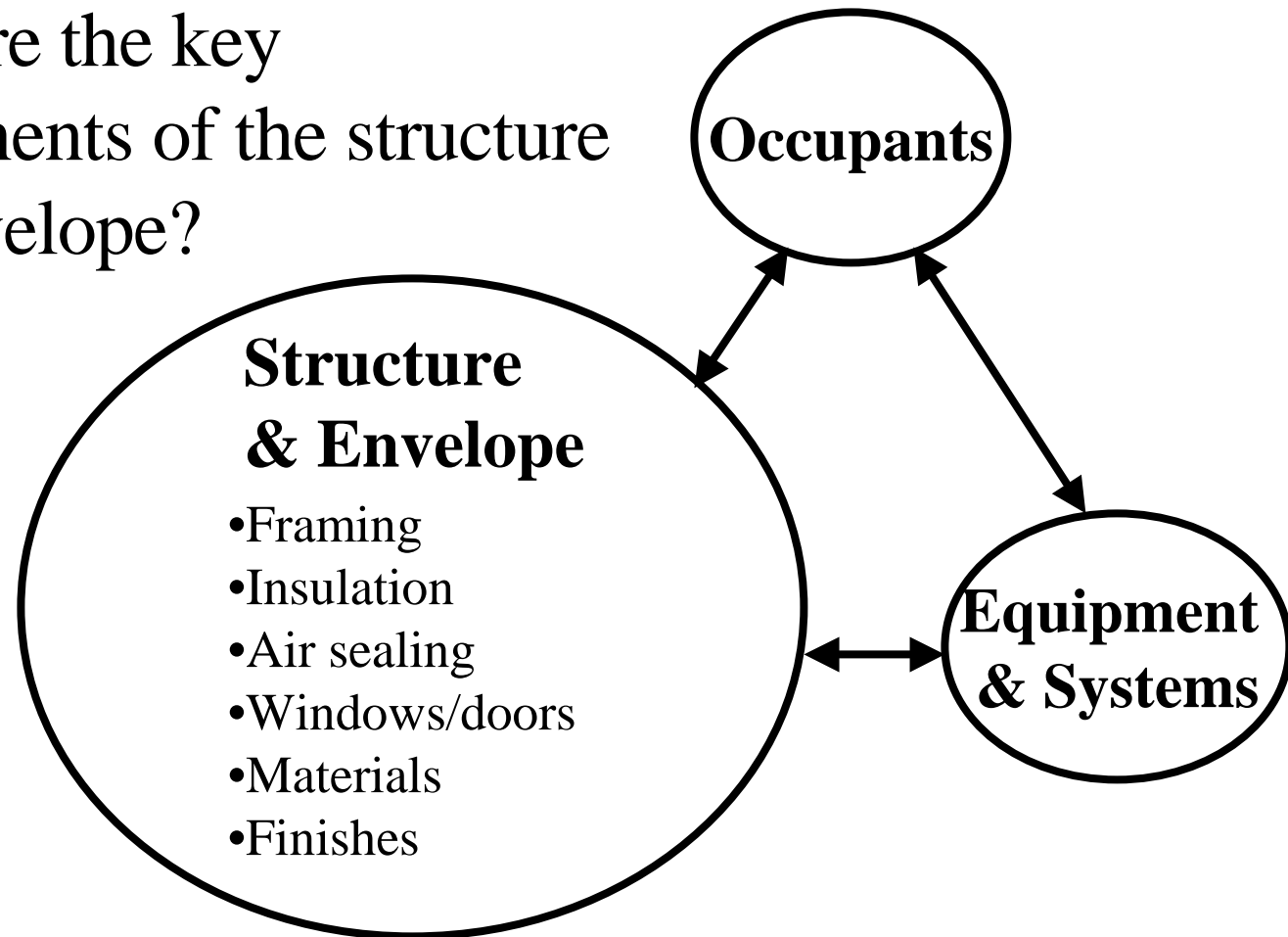


Basic Requirements of a Wall System

- Control heat flow
- Control air flow
- Control water & vapor flow
- Control rain penetration
- Control light & solar gain
- Control noise
- Be durable
- Provide strength & rigidity

The Structure...

- What are the key components of the structure and envelope?

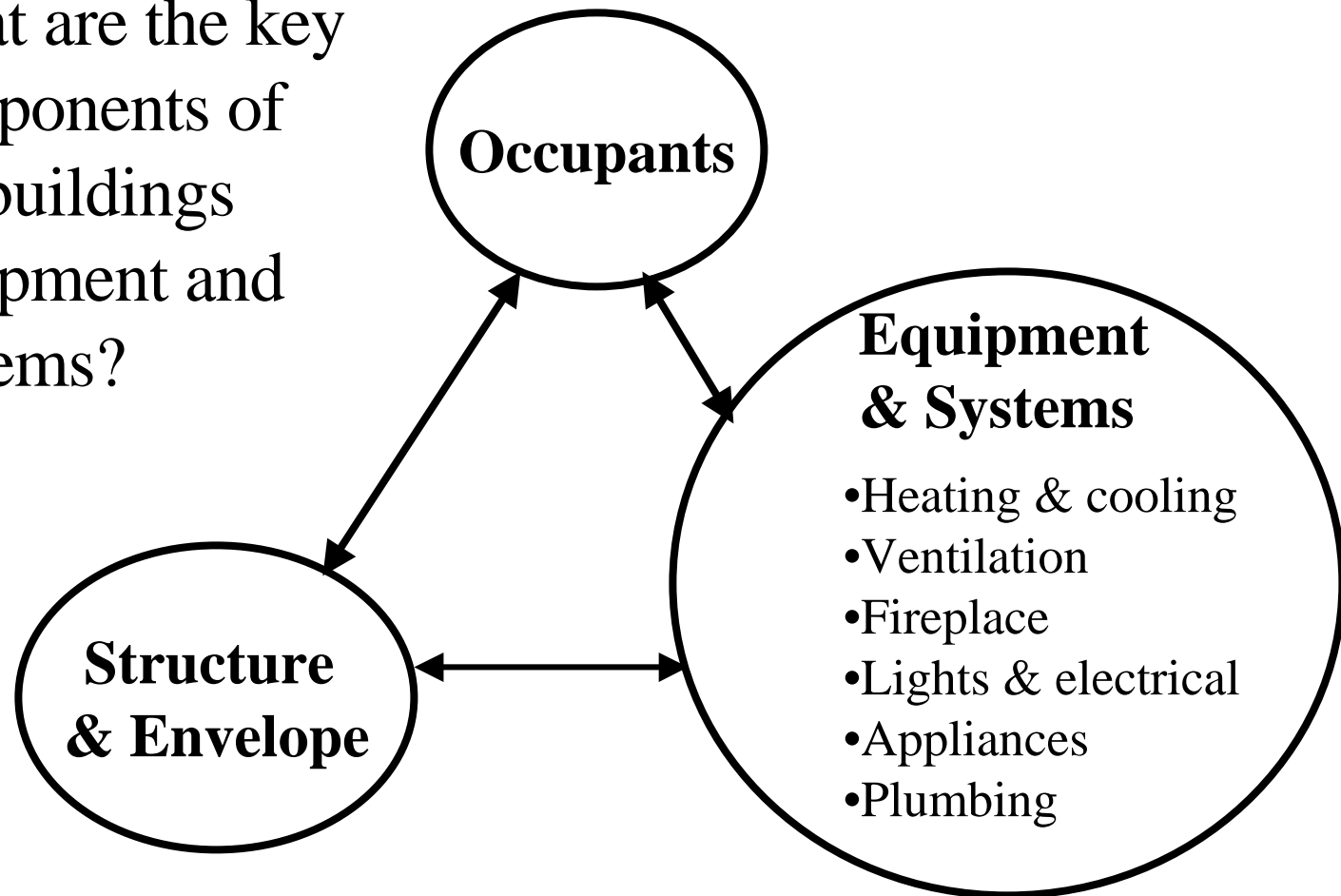


Systems for Comfort & Security

- Heating equipment
- Cooling equipment
- Humidification & dehumidification equipment
- Other systems
 - lights & appliances
 - electronics
 - security

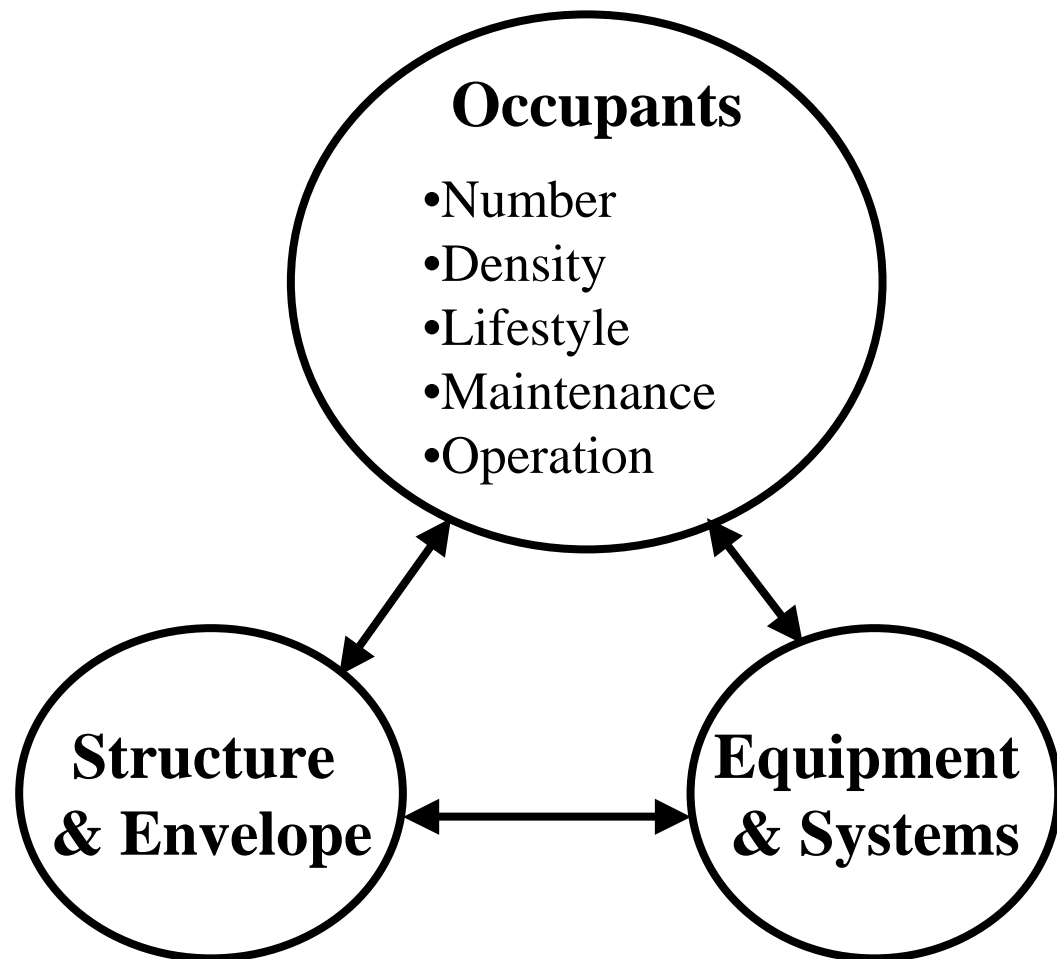
The Equipment...

- What are the key components of the buildings equipment and systems?



The People...

- How do people affect performance?



Common Callbacks in Residential Buildings - Various Climates

- High interior humidity level
- Wet crawl spaces & basements
- High cooling bills
- Uneven temperatures
- Drafts
- Indoor mold concentrations
- Insects

Common Callbacks in Residential Buildings - Various Climates

- Warped roof plywood
- Window performance - high solar gain
- Window performance - condensation
- Backdrafting of
combustion equipment
- Siding failures
- Stucco failures
- Poor air quality

Problem: Ice Dams, Frost in Attics

- **Solution:**
 - Continuous air/vapor barrier in ceiling
 - Sealed fixtures
 - All penetrations sealed
- **Benefits:**
 - Reduces heat loss & moisture flow through the ceiling which helps reduce ice dams and frost.

“You must learn from the mistakes of others. You can’t possibly live long enough to make them all yourself.”

Sam Levenson

Air & Energy Flow...

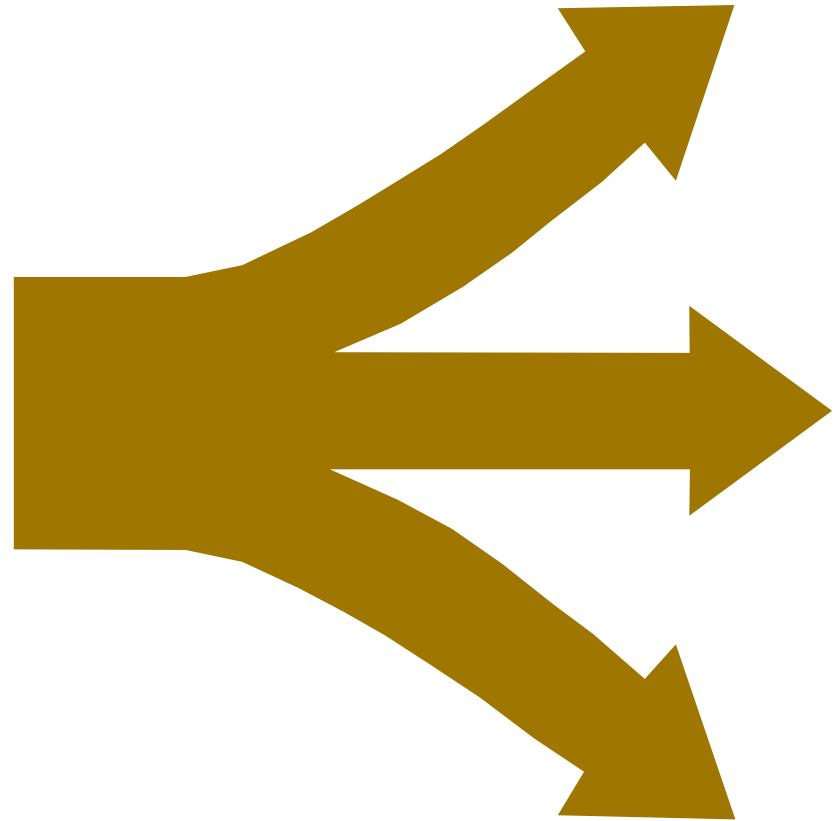
Understanding Pathways & Pressures

How does Air Flow?

- There must be a pathway and a pressure
 - Pathways can be direct or indirect
 - Through walls & ceilings
 - Pressures can be natural or mechanical
 - Through leaks, windows or systems

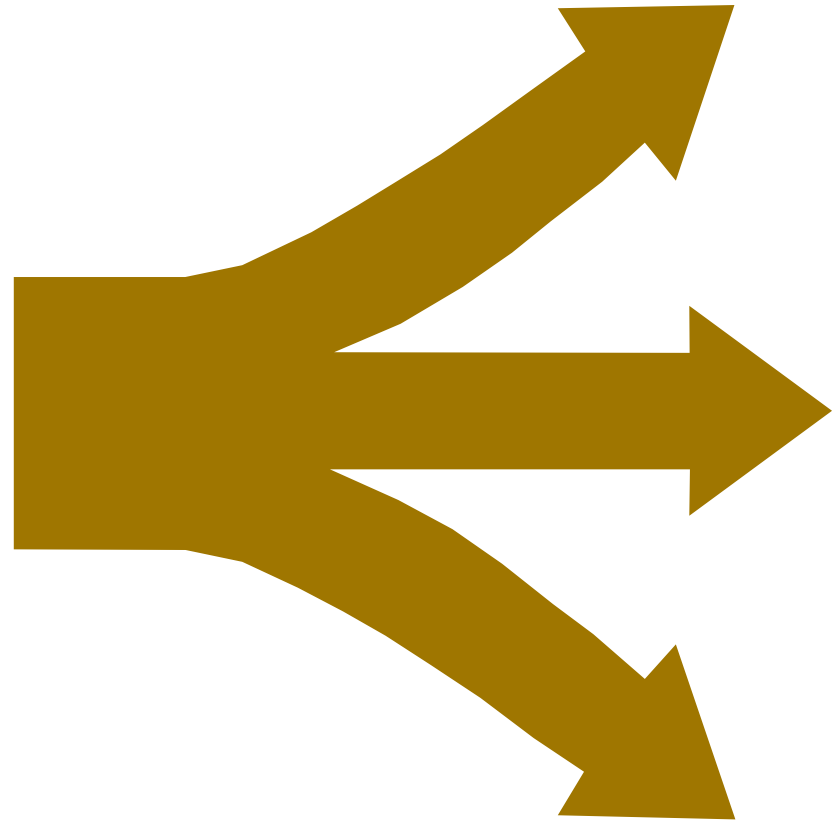
Air Leakage Pathways

- Direct through walls
 - Exterior outlet boxes
 - Framing penetrations
 - Plumbing penetrations
 - Recessed lights
 - Framing abnormalities
 - Speakers



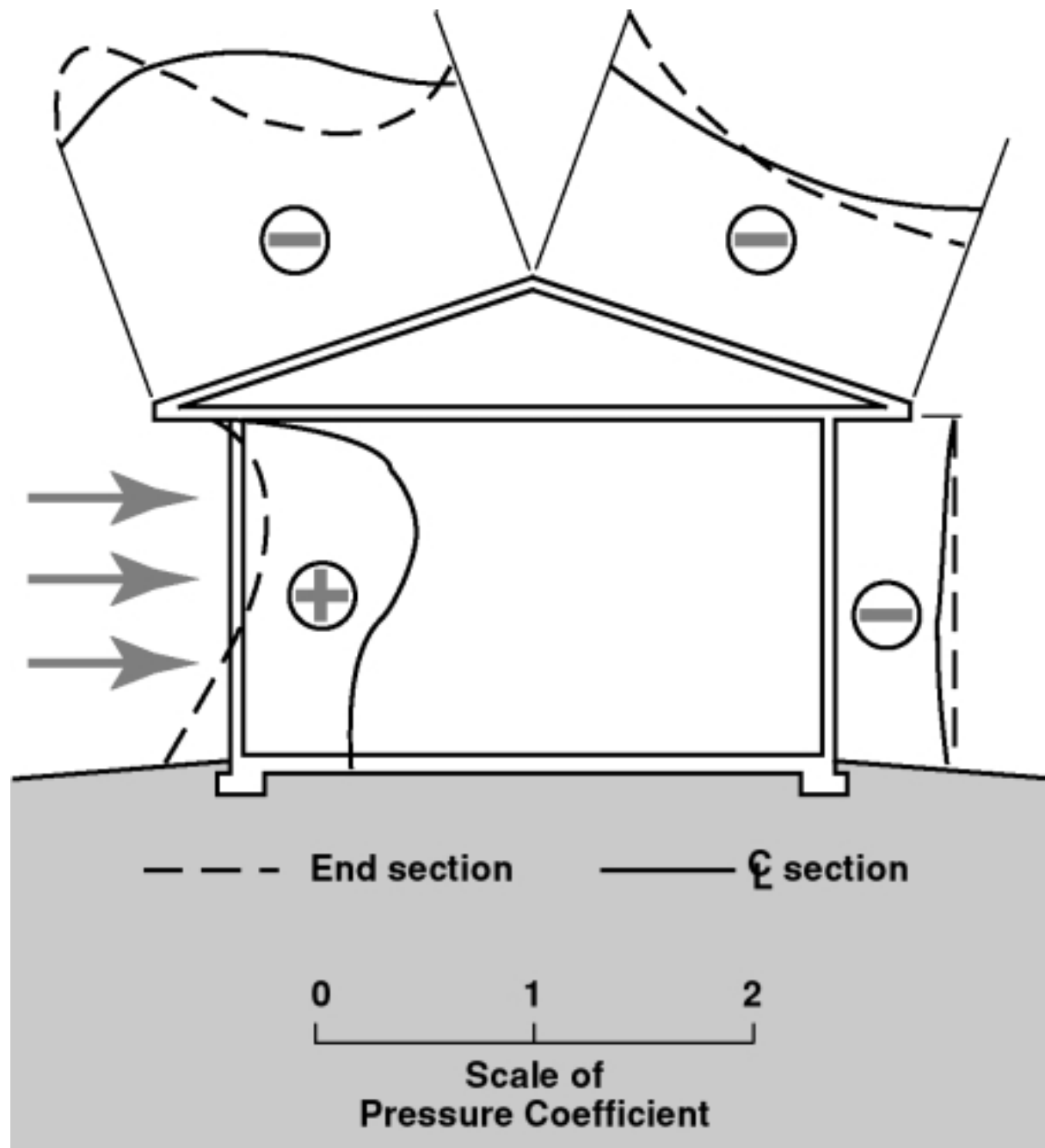
Air Leakage Pathways

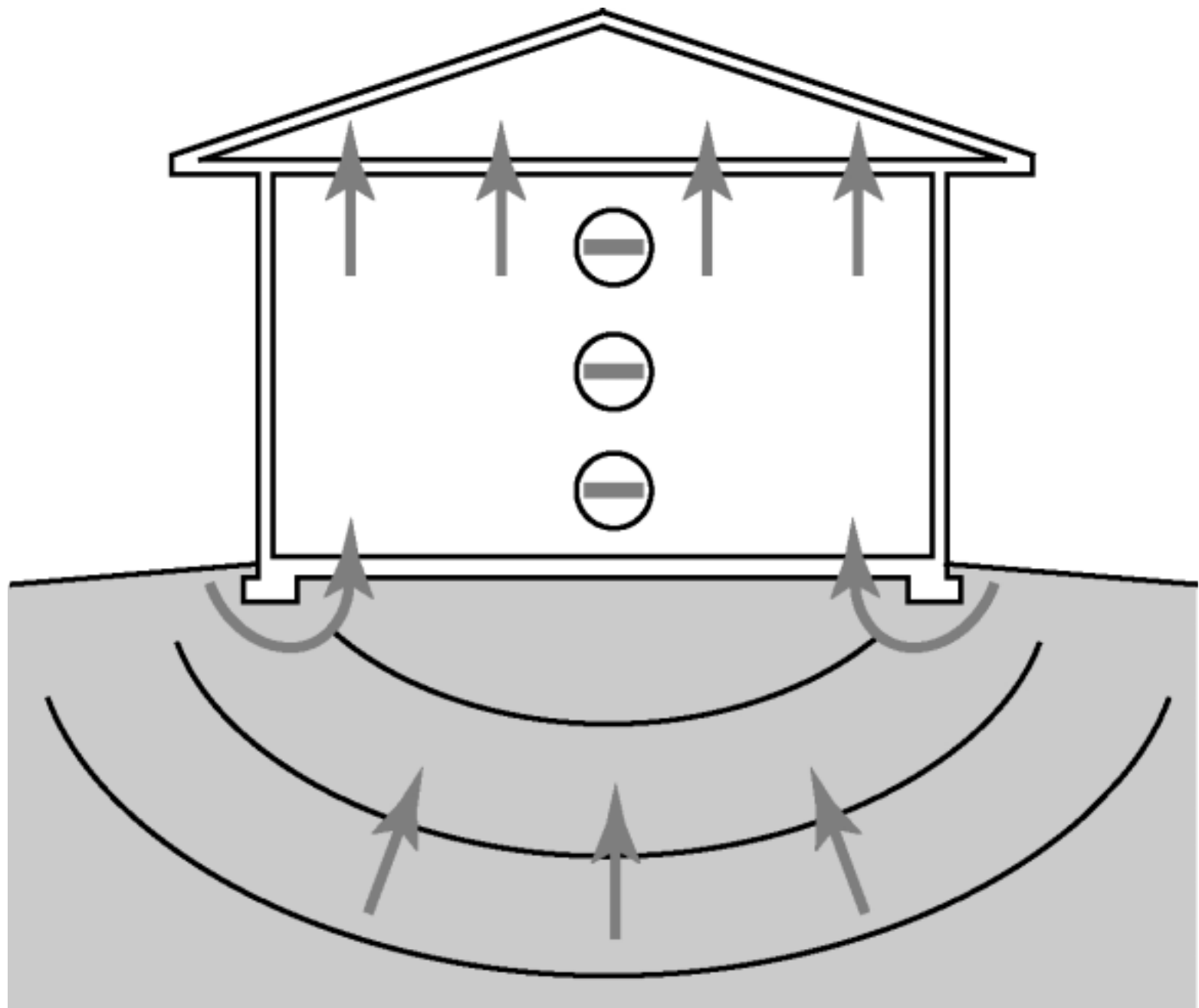
- Indirect through walls and ducts
 - interior outlet boxes
 - Framing penetrations
 - Plumbing penetrations
 - Recessed lights
 - Attic duct runs



Air Pressure in Buildings

- Natural forces
 - Wind Effect
 - Exterior penetrations allow air to infiltrate and reduce thermal insulation performance
 - Wind in must be equaled by air flow out
 - Stack Effect
 - Temperature difference drives air flow
 - Pressure planes establish directional flows (in/out)

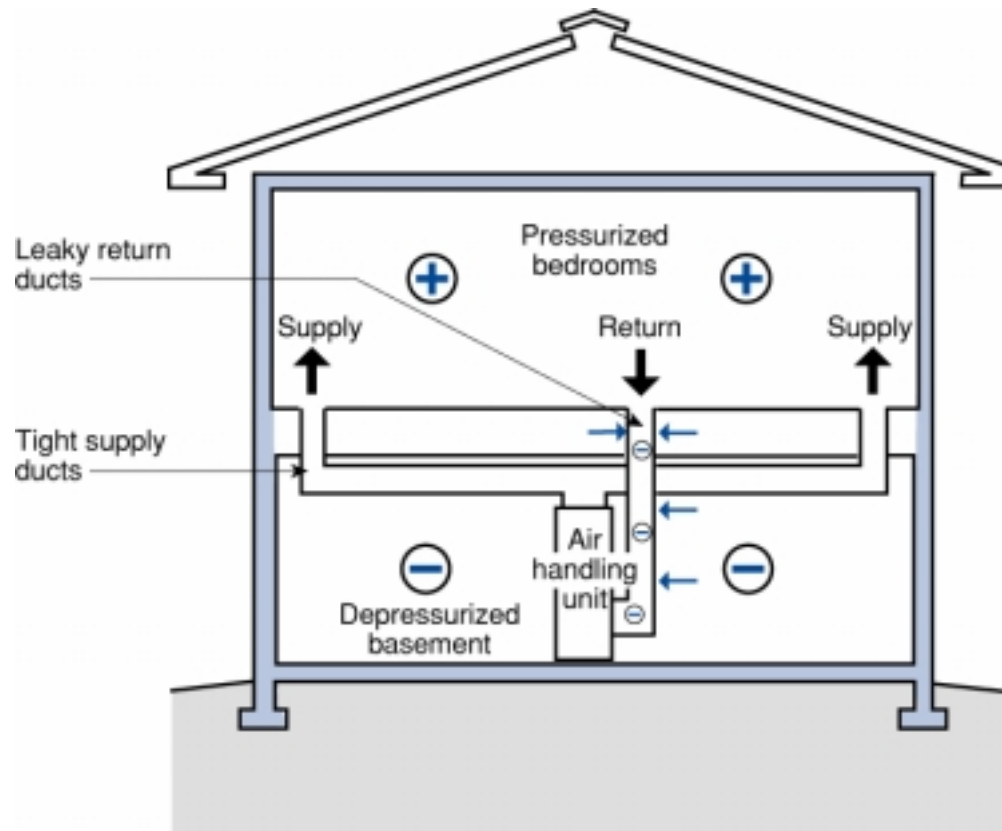




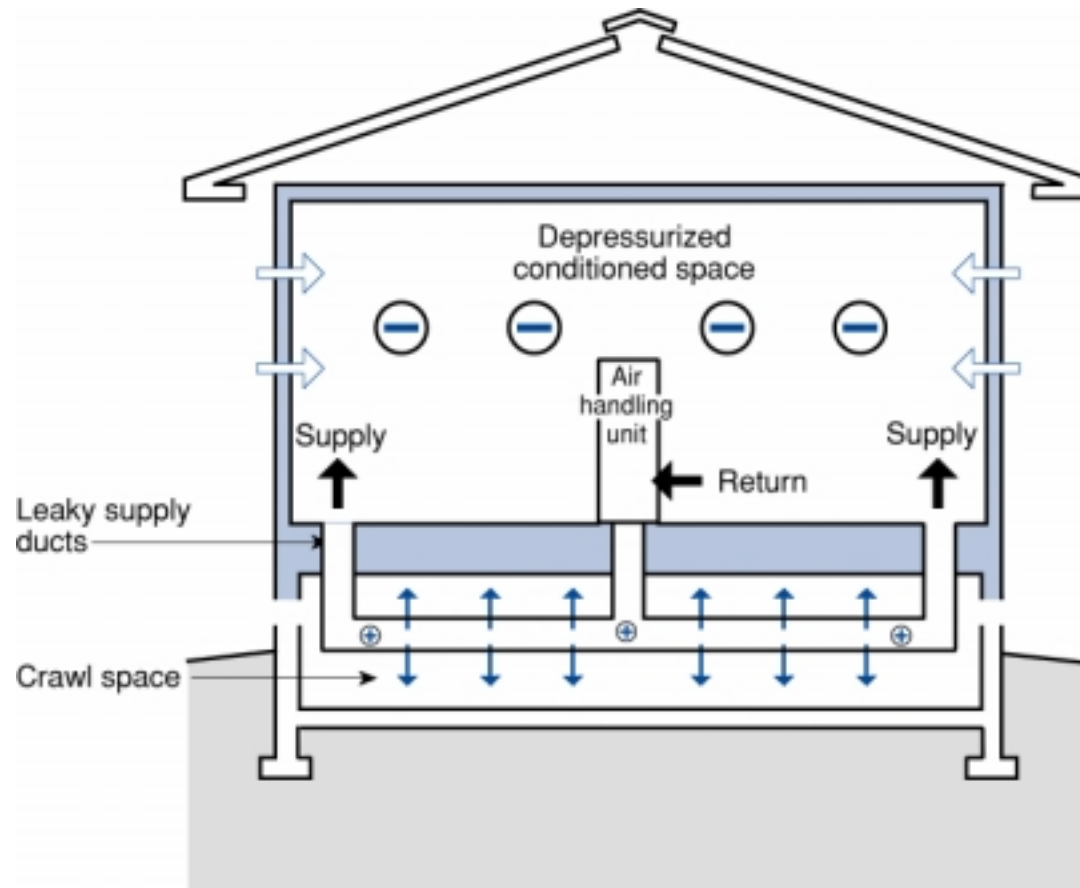
Working with Air Handlers

Consider the system interactions!

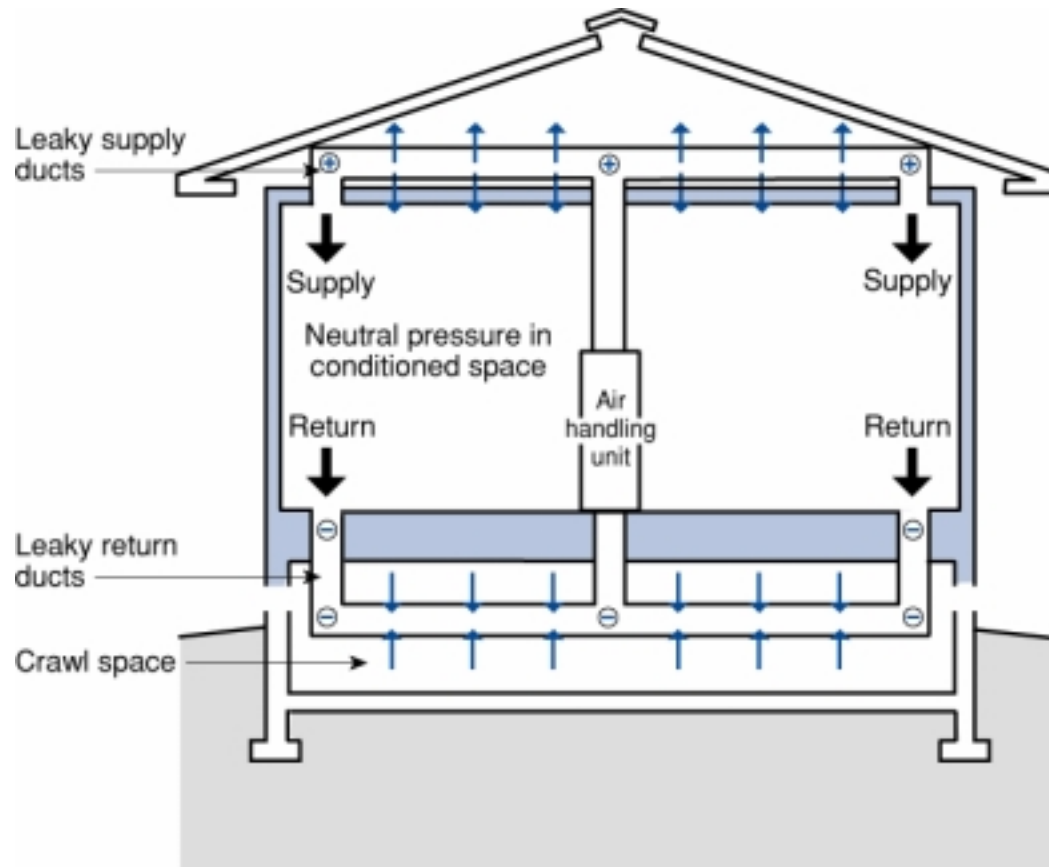
Leaky Ductwork and Air Handlers



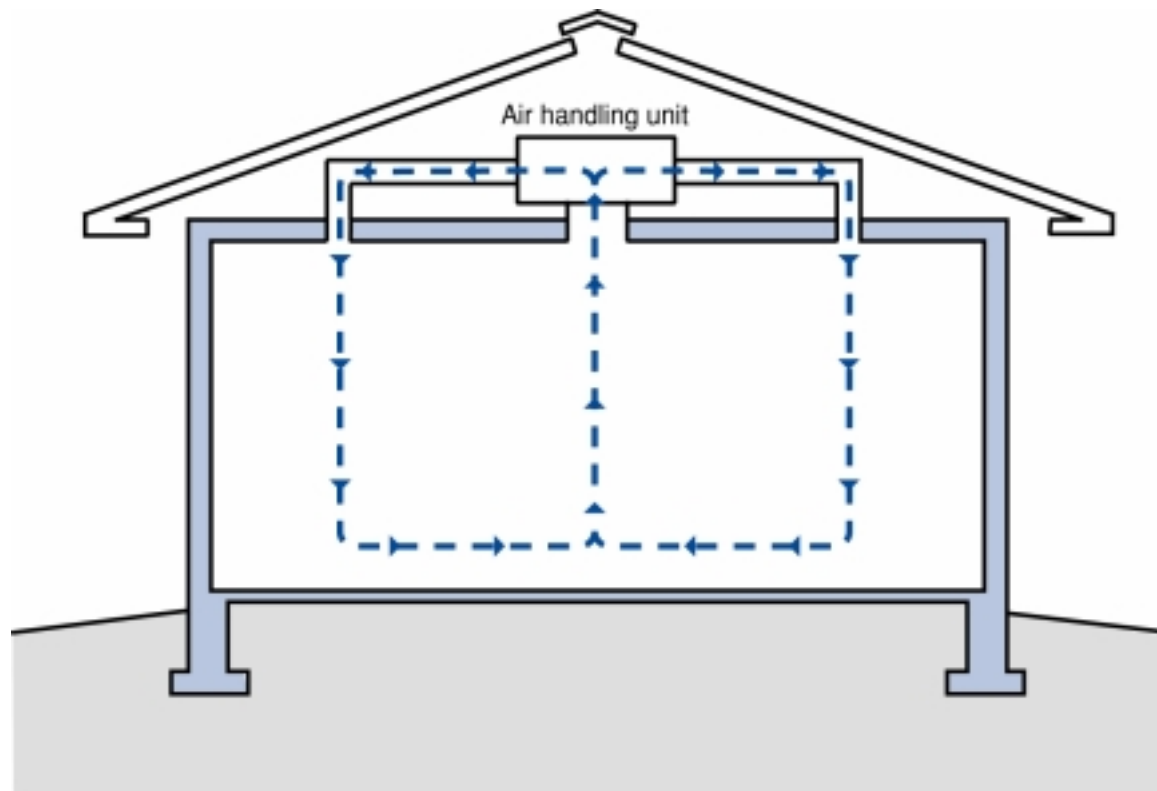
Leaky Supply Ductwork in Vented Crawlspace



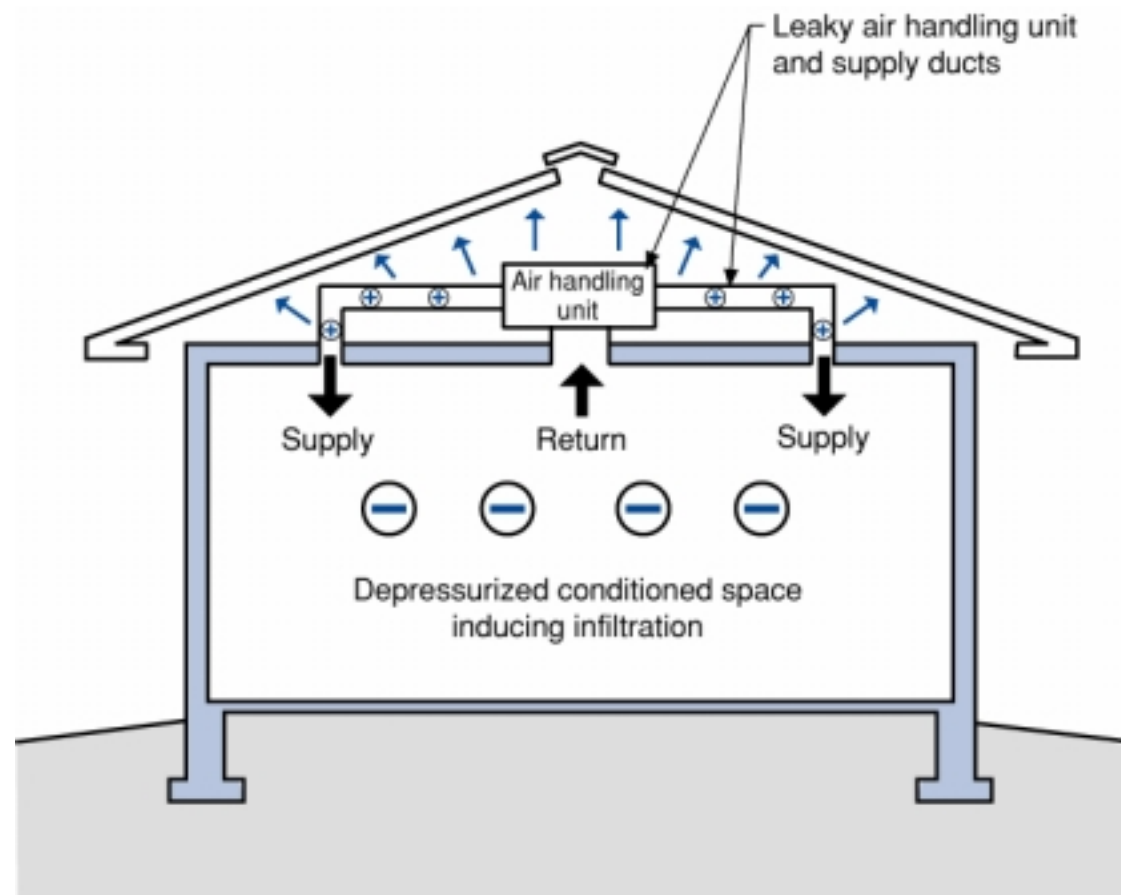
Leaky Supply and Return Ducts



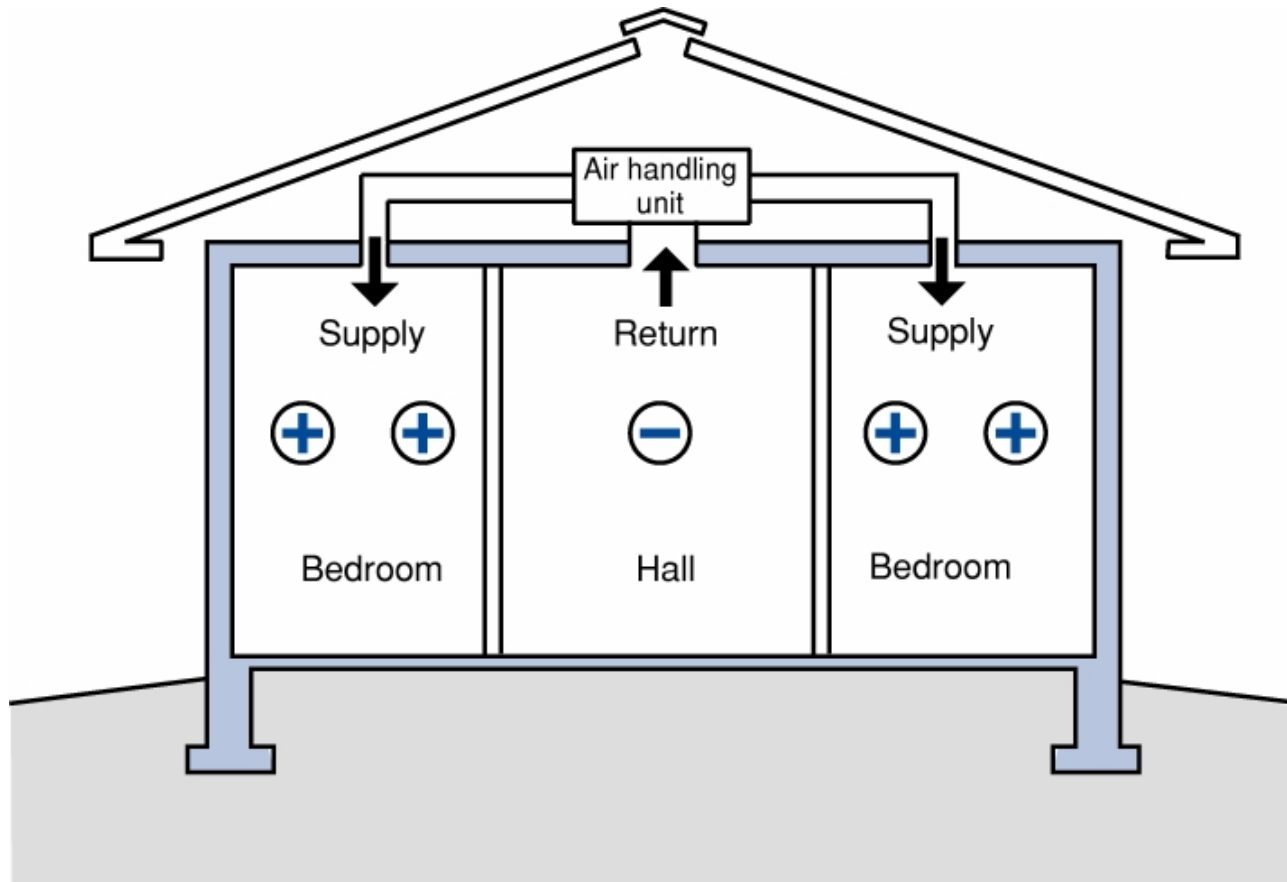
Ductwork and Air Handlers in Vented Attics



Leaky Ductwork and Air Handlers in Vented Attics



Insufficient Return Air Paths



Moisture...

Understanding the sources & flows

Forms of Moisture

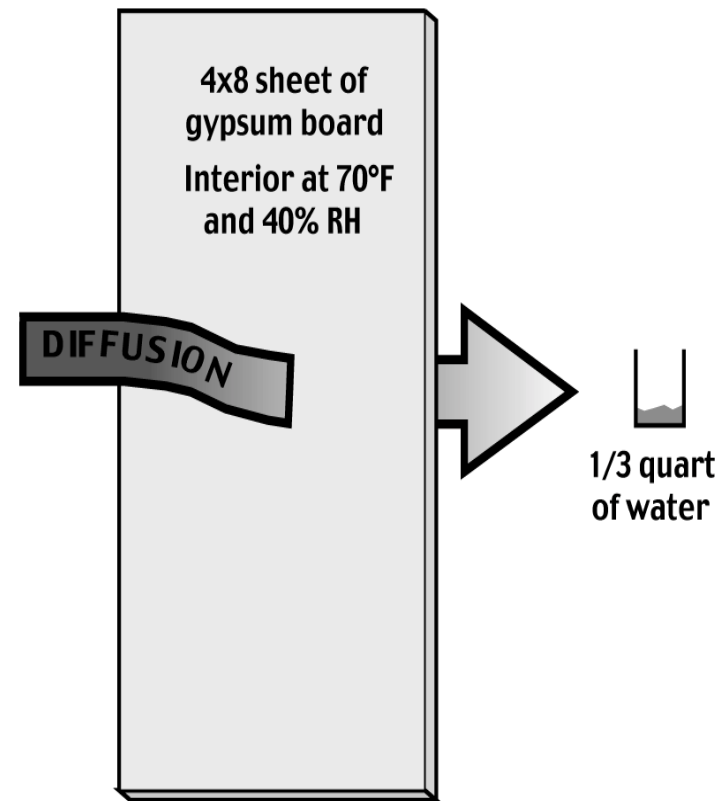
- Solid
 - Snow & ice
- Liquid
 - Rain, soil moisture & condensed vapor
- Gas (vapor)
 - Evaporated moisture

Moisture Flows

- Gravity
 - Rain & soil pressure
- Capillary
 - Material wicking
- Diffusion
 - Vapor pressure drive
- Air transport
 - Pressure induced flows of moisture laden air

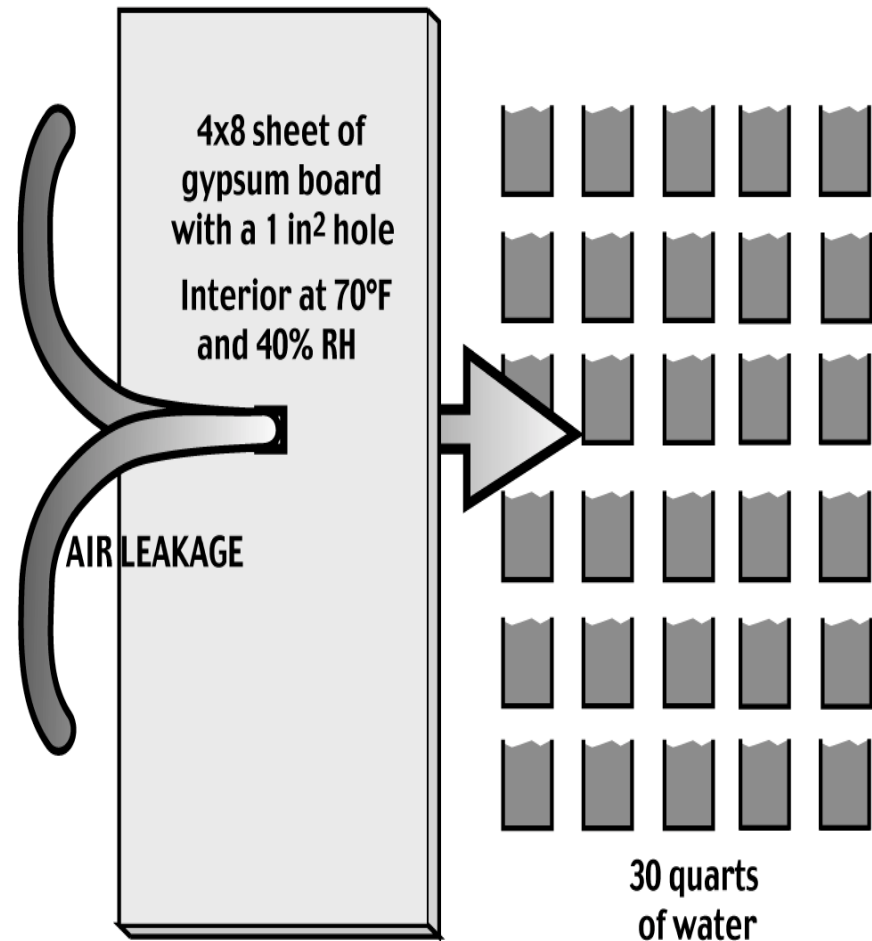
Diffusion

- Diffusion
 - Migration of moisture by means of vapor pressure differential
 - Occurs in either direction based on climate conditions and interior levels of humidity

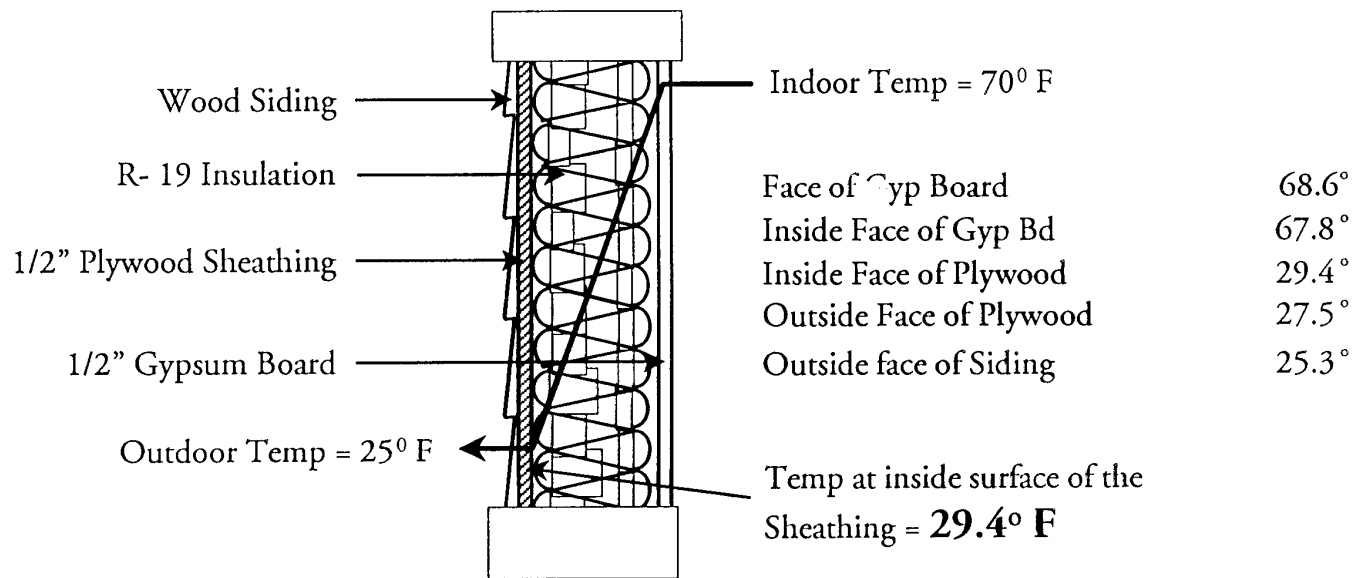


Air Transport of Water Vapor

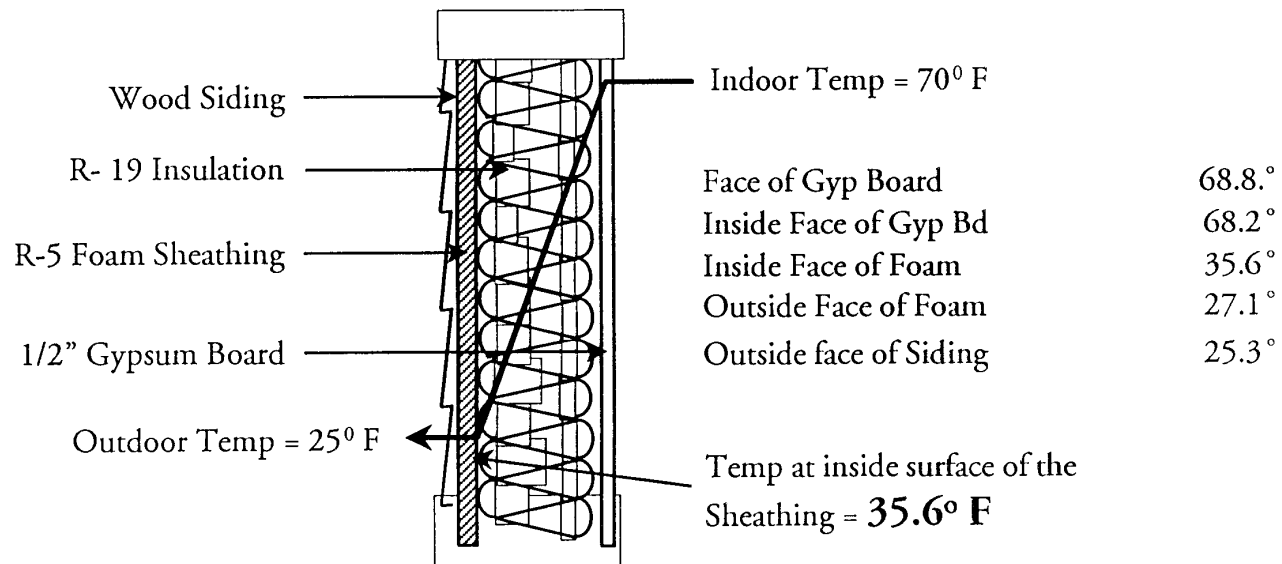
- Air leakage
 - Moisture flow
 - 4X8 Drywall
 - 70 F
 - 40% RH
 - 1square inch hole
- Flow quantity
 - 30 Quarts of water!!



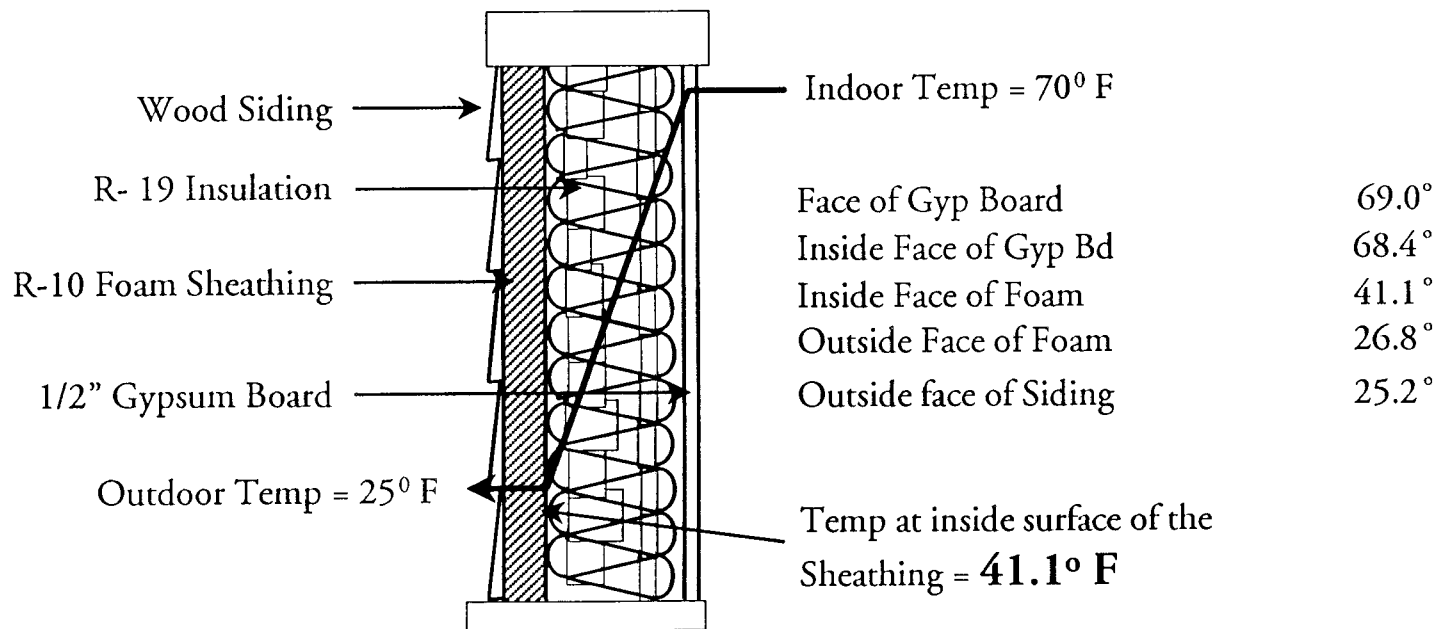
Temperature Profiles in a Wall



Temperature Profiles in a Wall



Temperature Profiles in a Wall



Moisture Sources

- External
 - Above grade
 - Below grade
- Internal
 - Building materials
 - Occupants
 - Processes

Strategies to Control Liquid Flow through the Building Envelope

- Flashing systems
- Weather barriers
- Rain screens
- Foundation drainage system
- Capillary breaks or non-porous materials

Strategies to Control Vapor Flow through the Building Envelope

- Vapor retarders
- Air barriers
- Manage interior humidity levels
- Manage air pressures

Strategies to Control Moisture inside the Building

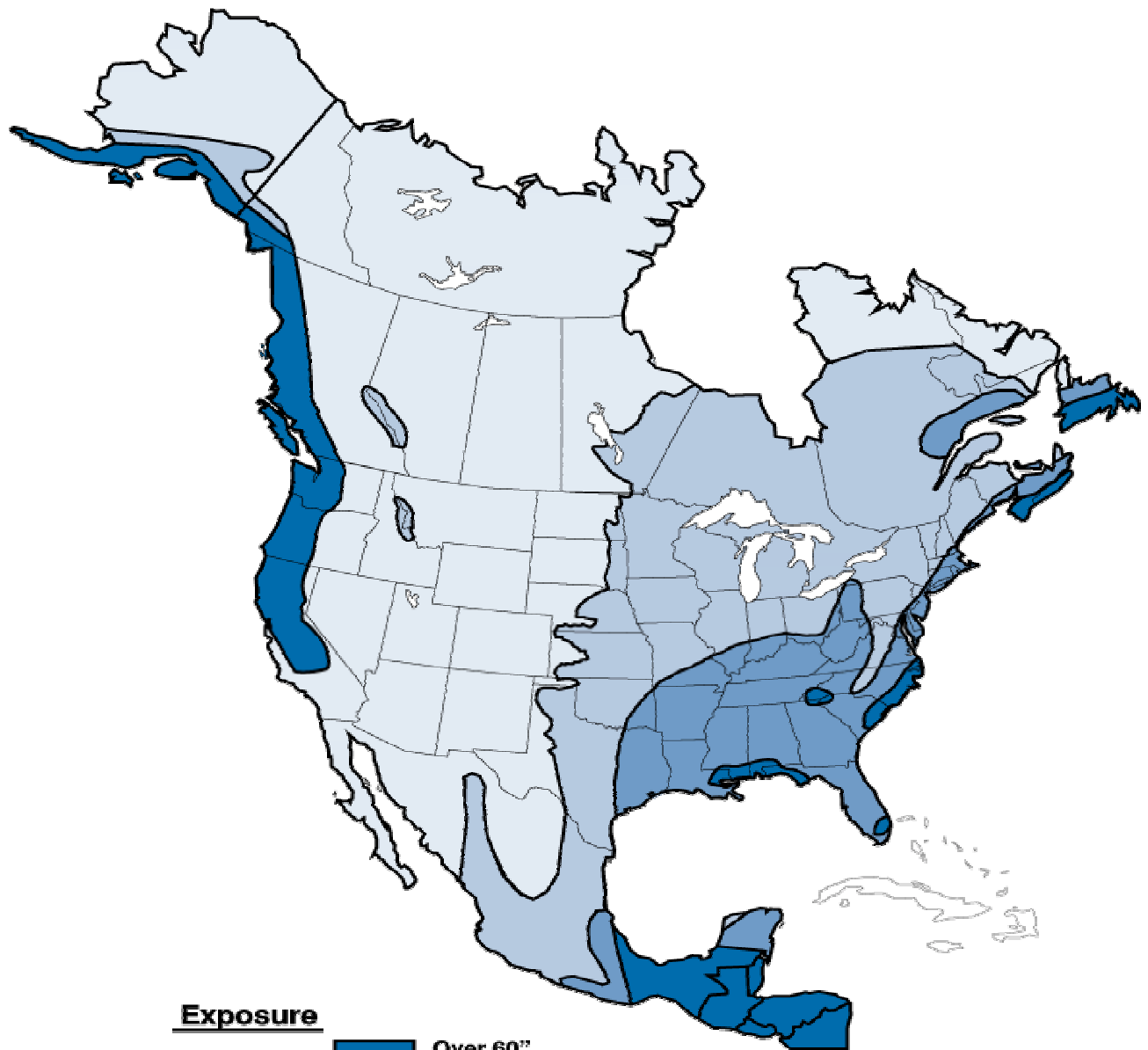
- Source control
 - Vent clothes dryers
 - Vent bathroom moisture
- Moisture removal
 - Dehumidification
 - Ventilation

Strategies to Control Condensation inside the Building





- Manage interior humidity levels
 - Occupant education
 - Ventilation
- Control surface temperatures
 - Increase insulation
 - Use warm edge windows
 - Avoid thermal bridges

Solutions to Common Problems

Annual Rainfall Map



Exposure

Extreme		Over 60" Pressure Equalized Rain Screen/Pressure Moderated Screen
High		50" - 60" Rain Screen
Moderate		20" - 50" Drainage Plane
Low		Under 20" Face Seal

Indoor Air Quality...

Understanding sources and solutions

The Nature of IAQ & Health

- Health Impacts
 - Acute
 - Chronic
- Occupant Sensitivities
 - Age
 - General health
 - Duration of exposure
 - Level of pollutant concentration

Fact:

1 in 3 people have an allergy
severe enough to seek
medical attention on a routine
basis.

—American Lung Association

Fact:

Allergies and asthma cost Americans \$10 billion/year in medical visits, \$51 million in prescriptions and \$1.5 billion in over the counter relief.

— American Demographics & American Lung Association

Pollutant Sources

- External

- Outdoor air
- Attached garages
- Soil gasses
- Exterior applied insecticides



- Internal

- Building materials
- Combustion equipment
- Occupant
- Activities
 - cooking
 - cleaning
 - hobbies
- Furnishings
- Mold & other biologicals

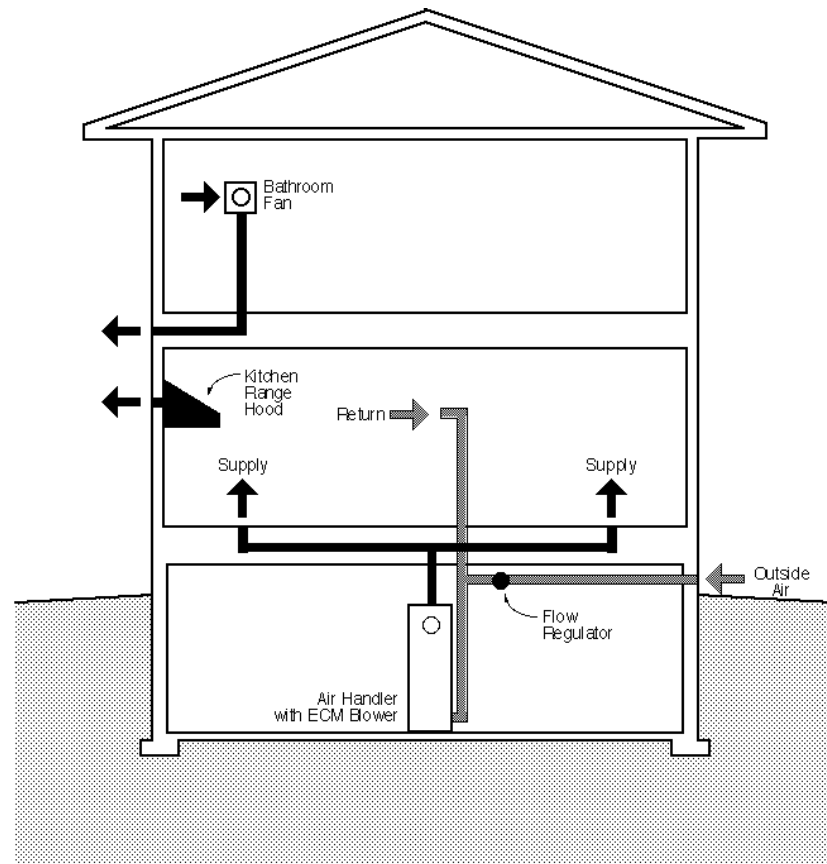
Pollutant Removal Strategies

- Source Control
 - Remove the pollutant
- Dilution
 - Mixing
 - Point source removal
 - General ventilation
- Filtration
 - Spot
 - General

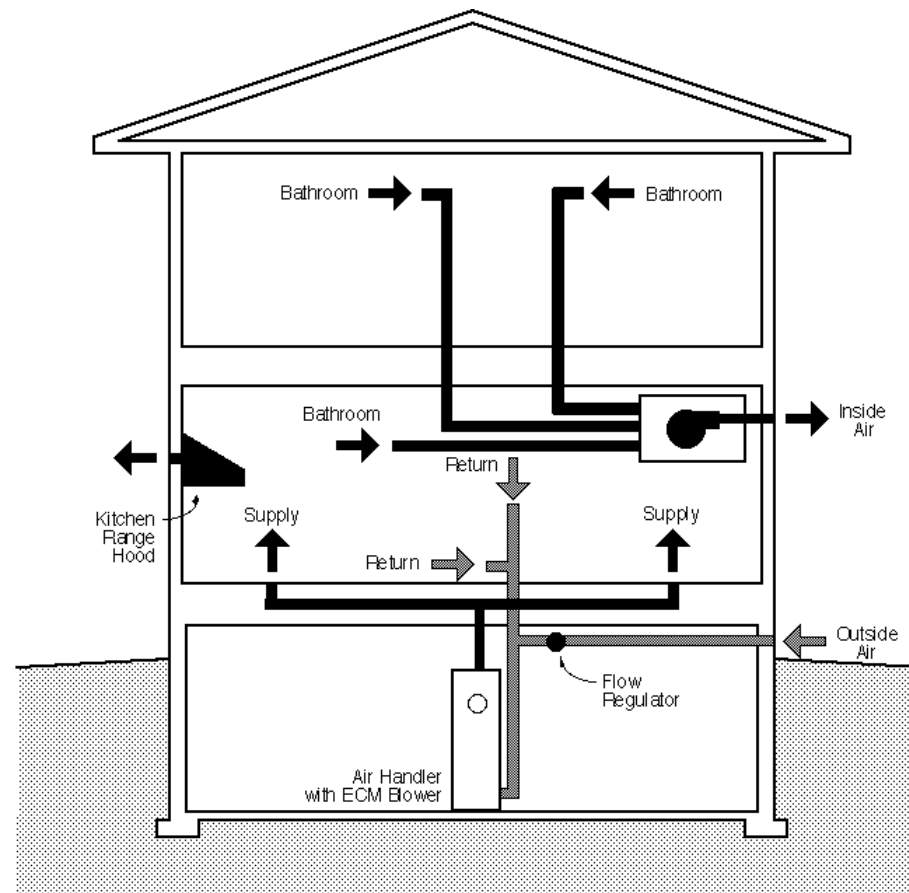


Ventilation Strategies

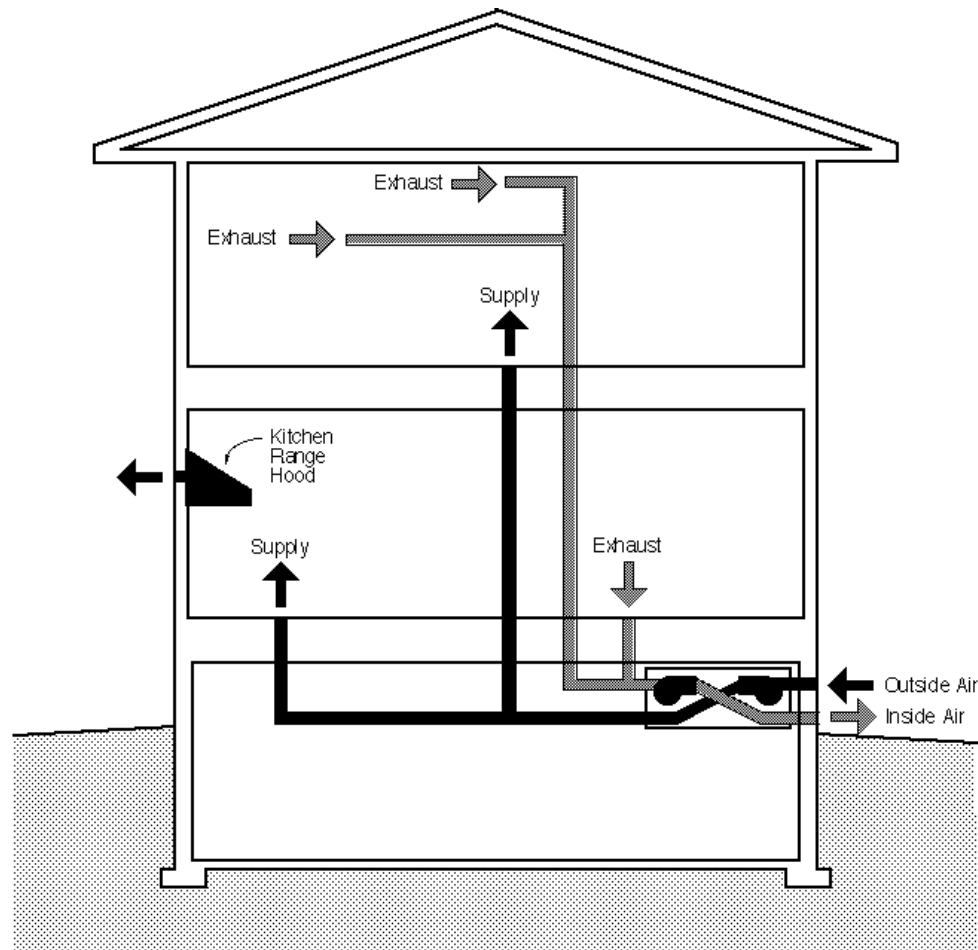
- Consider the options and methods to source point and volume ventilate
- Use quiet, reliable systems



Ventilation Strategies



Ventilation Strategies



Advantage to Homeowner

- Improve Health and Safety
 - Provide ventilation & filtration strategies
 - Exercise source control
- Increase Energy Efficiency
 - Increase affordability
 - Improve comfort
- Improved Durability
 - Reduced maintenance

System Improvements

- Building Envelope Design
- Structural or Framing Systems
- Building Enclosure (Air Flow Control)
- Insulation Systems
- Mechanical Systems
- Airflow Distribution Systems

For Additional Information...

- Journal of Light Construction
- Fine Homebuilding
- www.sheltersupply.com
- www.eeba.org
- www.healthhouse.org
- 888-Star Yes: for Energy Star Homes Info.

Thank You!